Lawrence Livermore National Laboratory

Science & Technology REVIEW

October/November 2014

LIVERMORE GARNERS 4 R&D100 AWARDS

Also in this issue:

International Nuclear Forensics Collaboration

About the Cover

Laboratory researchers won four R&D 100 awards in *R&D Magazine*'s annual competition for the top 100 industrial innovations worldwide. Highlights beginning on p. 4 describe the award-winning technologies. They include a superconducting tunnel junction x-ray spectrometer for characterizing materials; a field-portable thin-layer-chromatography kit for detecting and identifying hazardous materials; a convergent polishing process for flat and spherical glass optics; and an extreme-power, ultralow-loss, dispersive element for combining laser beams. Since 1978, Livermore researchers have received 152 R&D 100 awards. The R&D 100 logo is reprinted in this issue with permission from *R&D Magazine*. (Background graphic © memorialphoto – Fotolia.com.)

Cover design: Amy E. Henke

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At Lawrence Livermore National Laboratory, we focus on science and technology research to ensure our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published eight times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

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Getting More Out of Lithium-Ion Batteries

A research team led by Livermore scientist Brandon Wood and Rice University physicist Boris Yakobson has developed a theoretical model that predicts how carbon components will perform as electrodes in lithium-ion batteries. The team's model could lead to advances in the storage capacity of lithium-ion batteries, thus extending their performance life for applications from cell phones to electric vehicles and aerospace technologies.

Several characteristics of lithium-ion battery performance—capacity, voltage, and energy density—are determined by the binding between lithium ions and the electrode material. Yet subtle changes in the structure, chemistry, and shape of an electrode can affect lithium-ion bond strength. The Livermore–Rice research, which appeared in the July 11, 2014, edition of *Physical Review Letters*, predicts that the strength of this binding is based on intrinsic characteristics of the carbon materials used as battery anodes.

In this study, the team investigated the interactions of lithium with carbon substrates including pristine, defective, and strained graphene; planar carbon clusters; nanotubes; carbon edges; and multilayer stacks. Wood and Rice University's Yuanyue Liu looked for a "descriptor" that would capture the essential physics of interactions between lithium and the carbon materials. "Our descriptor predicts the performance of a variety of materials," Wood says, "and finds combinations in which the underlying physics is similar, even if the materials' structures, morphologies, or chemistries differ. Our model is a predictive tool that could accelerate design and discovery." The model also provides guidelines for engineering more effective anodes by modifying the electronic and chemical properties of other candidate materials.

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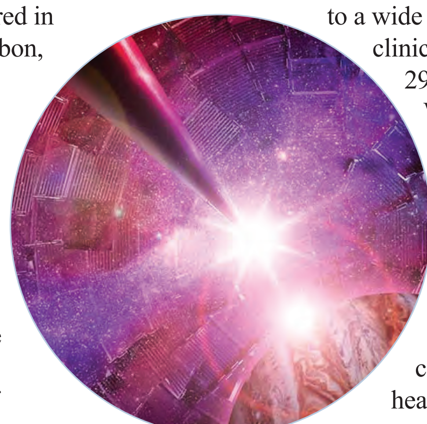
Peering Inside Giant Planets

Using the National Ignition Facility (NIF), the world's most energetic laser, a collaboration involving Lawrence Livermore, the University of California at Berkeley, and Princeton University has experimentally re-created the conditions that exist inside giant planets such as Jupiter and Uranus. (Interior of the NIF target chamber is shown at right.) The team's study, featured in the July 16, 2014, edition of *Nature*, focused on carbon, which has an important role in most planets. By re-creating these conditions in a laboratory setting, researchers can measure material properties that control how giant planets evolve over time, which is essential information for understanding how these planets form.



For this study, the team used 176 of NIF's 192 lasers to produce a pressure wave that compressed a diamond sample under pressure more than 50 million times that of Earth's atmosphere, which is comparable to the pressure at the center of Jupiter and Saturn. The sample vaporized in less than 10-billionths of a second. Although diamond (a form of carbon) is the least compressible material known, the researchers compressed it to a density greater than that of lead at ambient conditions.

Such pressures have been reached in experiments with shock waves, which create temperatures too high to be realistic for planetary interiors. To meet the technical challenge of keeping temperatures low enough to be relevant, the NIF team carefully tuned the rate at which laser intensity changes with time. "Having the ability to explore matter at atomic-scale pressures provides new constraints for dense matter theories and planetary evolution models," says Livermore physicist and team member Rip Collins.

The data described in this work are among the first tests for predictions made in quantum mechanics more than 80 years ago. Although the NIF data and early theory agree, the team found important differences, suggesting unknown properties for diamond under extreme compression. Future experiments at NIF will focus on unlocking these mysteries.

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Screening Technology for Emerging Viral Diseases

An international team of researchers has discovered a potential new use for the Lawrence Livermore Microbial Detection Array (LLMDA)—providing a rapid surveillance approach to identify emerging viral diseases. In the team's paper, published in the June 25, 2014, edition of *PLOS ONE*, the researchers note that emerging viruses are often difficult to diagnose because their symptoms are similar to those of more common viruses. Quickly identifying the correct virus is crucial for patient treatment and for containing a potential epidemic.

Developed in 2008, LLMDA detects microbes by using a checkerboard pattern of probes in the middle of a 2.5-centimeter-wide, 7.5-centimeter-long glass slide. The instrument occupies a niche role between the polymerase chain reaction (PCR) technique and DNA sequencing. One advantage of LLMDA is that it can perform thousands of tests in parallel within 24 hours. PCR, although a faster approach, can run only dozens of tests at a time. The research team, which included Livermore scientists Shea Gardner and Kevin McLoughlin, found that LLMDA is sensitive to a wide range of emerging viruses. In a study with both clinical and nonclinical samples, the array identified 29 emerging viruses, including Dengue fever and West Nile virus. The current version of LLMDA can identify 4,377 viruses and 5,457 bacteria as well as a combined total of 775 protozoa, fungi, and archaea species.

Emerging viruses are normally endemic to tropical and subtropical regions of the world, but increased global travel helps spread viruses into new regions. "With this study, we are closer to developing the technology so that public health laboratories can use it to screen samples for unexpected viruses in the population," says McLoughlin.

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Commentary by Gregory Suski

Exploration and Vision Lead to New Solutions

CONTINUING the Laboratory's long history of extraordinary success in garnering R&D 100 awards, four Lawrence Livermore teams received this coveted prize in 2014 for their innovative technologies. Their accomplishment adds to an impressive record of 152 R&D 100 awards that began with our first award for diamond machining of optics in 1978. Over the years, Laboratory Directed Research and Development (LDRD) investments have led to many of our R&D 100 awards. This year is no exception with two of the four award-winning technologies evolving from LDRD-funded research.

Since 1963, *R&D Magazine* has selected 100 technologically significant new products or processes each year and honored them with the now widely recognized R&D 100 Award. Winning nominations, which come from private industry, government agencies, universities, and research institutes around the world, are chosen by the magazine's editors based on peer reviews from panels of experts in relevant disciplines. The judges look for technologies that promise to change people's lives in one or more of 20 categories, spanning such areas as software and communications technologies, materials science, chemistry, electronics, life sciences, consumer goods, safety, and security.

Many award-winning technologies have become household names or game-changing technical advances, including the Polacolor color film (1963), flashcube (1965), automated teller machine (1973), facsimile machine (1975), liquid crystal display (1980), touch-sensitive screen and color graphics printer (1986), digital compact cassette (1993), and high-definition television (1998). Livermore's previous R&D 100 awards are among winning technologies that have had huge impacts on U.S. industry. These include a laser-shot peening system for strengthening metals (1998), a technology that has saved the world's aviation industry hundreds of millions of dollars, and DYNA3D (1994), which revolutionized crash simulation in the auto industry by accurately predicting vehicle behavior in collisions. More recently, the Laboratory's winning technologies include plastic scintillators to better detect nuclear smuggling, the first long-term artificial retinal prosthesis, and enabling capabilities for fusion experiments.

R&D 100 awards captured by Livermore are a metric of successful innovation and an indicator of influence beyond the Laboratory. They are also a testament to the uniqueness of the work done by Livermore's talented and dedicated scientists and engineers. A considerable amount of research and development is required before a technology or product is ready to enter the R&D 100 competition. Our developers then work with the Laboratory's Industrial Partnerships Office, and in some cases external partners, to describe the principal applications of the product or technology and how it may benefit the market it serves. This teamwork has contributed to the Laboratory's exceptional track record of successes in the annual competition.

This year's four winners are described in this issue of *Science & Technology Review*. A superconducting tunnel junction x-ray spectrometer (see p. 4) for characterizing materials offers more than 10 times higher energy resolution than current x-ray spectrometers based on silicon or germanium semiconductors. The spectrometer was developed in collaboration with STAR Cryoelectronics, LLC.

The microTLC™ (thin-layer chromatography) field-portable kit (see p. 6), originally developed to detect and identify military explosives, has been modified in collaboration with Field Forensics, Inc., to also identify illicit drugs, pesticides, and other compounds.

Another 2014 winner is a Livermore-developed convergent polishing process and system (see p. 8) that quickly and inexpensively finishes flat and spherical glass optics in a single iteration, regardless of a workpiece's initial shape.

Finally, the development of an extreme-power, ultralow-loss, dispersive element (see p. 10) is a technical innovation that spectrally combines many small laser beams to reach unseen output levels. Developed in conjunction with Lockheed Martin and Advanced Thin Films, Inc., this novel approach produces a single high-power, high-efficiency, near-diffraction-limited beam.

Congratulations to the many researchers featured in the articles describing these R&D 100 awards for their outstanding efforts. Being listed as one of the top 100 innovations worldwide is an honor, and four awards for Livermore is truly an impressive accomplishment and an indicator of exceptional work, fertile imaginations, and talented people shaping our nation's future.

■ Gregory Suski is acting deputy director of Science and Technology.

A Super, Cool Device for Material Characterization

THE color of an object reveals some details about its composition. For instance, gold is distinguishable from silver because of its yellow hue. But to determine an object's exact elemental and chemical makeup, researchers require an in-depth technique such as x-ray spectroscopy. With this method, x rays or high-energy electrons excite a sample, causing the sample to emit x rays whose energy, or color, spectra are specific to each element within the sample, similar to an "x-ray fingerprint."

Semiconductor-based x-ray detectors, also called energy-dispersive spectrometers, are the most widely used instruments for x-ray spectroscopy because these inexpensive devices are easy to use and provide results quickly. However, their relatively poor energy resolution can make it extremely difficult for x-ray measurements to distinguish different elements, especially at low energies or in samples with multiple elements. Wavelength dispersive x-ray spectrometers, which use crystals and gratings to obtain a complete x-ray spectrum, provide excellent energy resolution. However, their complicated operating requirements are time-intensive, difficult to perform, and more susceptible to systematic errors.

The superconducting tunnel junction (STJ) x-ray spectrometer, an R&D 100 Award–winning technology, bridges that gap between efficiency and resolution, offering 10 times higher accuracy in a user-friendly format. The higher resolution allows for the clear separation of characteristic x-ray lines even at low energies and in complicated multi-element samples, which is beneficial for technological, medical, and forensic applications. Lawrence Livermore partnered with STAR Cryoelectronics, LLC, to codevelop this technology.

Cooling It Down

The STJ x-ray spectrometer operates similarly to conventional silicon-based systems, wherein x-ray absorption by the sensor excites a number of free charges above an energy gap, and the temporary increase in the current provides a direct measure of the x-ray energy. The difference is that superconductors, such as those in the STJ x-ray spectrometer, feature an energy gap of just about 1 millielectronvolt compared with the 1,000 times larger 1-electronvolt gap in semiconductors. As a result, with the same

Development team for the superconducting tunnel junction (STJ) x-ray spectrometer: (from left) Owen Drury, Matt Carpenter (STAR Cryoelectronics, LLC), Stephan Friedrich, Jan Batteux, and Simon Labov. (Photo by George A. Kitrinos.)

Carpenter analyzes high-resolution spectra from the STJ x-ray spectrometer (shown on the table) to characterize a material sample. The rack contains the support electronics for spectrometer operation. (Photo by Roy Kaltschmidt of Lawrence Berkeley National Laboratory.)

energy, an STJ x ray excites 1,000 times more free charges in the superconductors, which in turn improves the energy resolution of the x-ray spectra by a factor of about 30.

Superconductor-based systems require refrigeration mechanisms that can keep temperatures low enough to suppress thermal leakage currents, which reduce the accuracy of the energy data. The cooling medium is typically liquid nitrogen or helium. However, the cost and difficulty of working with these materials has limited the use of superconducting systems to the scientific community. “To make this technology commercially viable and accessible to nonexperts, we developed an automated liquid-cryogen-free refrigeration system that allows for the operation of the instrument at 0.3 kelvins, low enough to suppress thermal leakage currents in the superconducting material,” says physicist Stephan Friedrich, who led the Livermore team.

A two-stage pulse tube refrigerator precools the sensor to 3 kelvins. From there, a two-stage adiabatic demagnetization refrigerator allows the system to attain a base temperature of less than 0.1 kelvins. The refrigeration system uses a long, shielded “cold finger” so that the sensor can operate within 2 centimeters of a room-temperature sample, while maintaining a temperature below 0.3 kelvins. “The system is fully automated,” says Friedrich. “It can be cooled with the simple push of a button.”

Improved Detection Capabilities

Superconducting x-ray detection technologies have been used for about two decades for scientific applications. One limitation of all superconducting x-ray sensors is that they are intrinsically small. Their tiny size affects the efficiency with which they can detect x rays from a sample, thus increasing the time required to acquire data for a complete x-ray fingerprint. The award-winning team has solved this problem by configuring detector arrays that can be added for even higher detection efficiency and faster detection speed. The entire superconducting sensor uses arrays of up to 112 high-quality tunnel junctions made from tantalum and aluminum.

The quality of a tunnel junction is dependent on producing an insulating ultrathin aluminum oxide tunnel barrier without any pinholes. Such defects increase the leakage current and thus the electronic noise in the detector. “STAR Cryoelectronics has optimized the sensor fabrication process and developed tunnel junctions with very low leakage current,” says Friedrich. The photolithographic fabrication process reproduces the requisite hundreds of sensors needed for the arrays. “With our sensor arrays, we have increased detection efficiency and reduced data-acquisition time by more than a factor of 100.”

From Lab to Market

The improved precision of the STJ x-ray spectrometer, along with its ease of operation, will make high-accuracy x-ray fingerprinting available to commercial users. During production, computer-chip manufacturers will be able to detect ever-smaller impurities that affect production yield. Biomedical companies will be able to detect lower concentrations of toxic metals in their samples. And forensic specialists could use the device to identify smaller traces of evidence from crime scenes.

Says Friedrich, “It is gratifying to see technologies we develop at the Laboratory successfully make the transition into commercial applications for use by the general population.” The STJ x-ray spectrometer provides a more effective way to characterize samples, which can lead to technological, environmental, and medical benefits.

—Caryn Meissner

Key Words: material characterization; R&D 100 Award; STAR Cryoelectronics, LLC; superconducting tunnel junction (STJ) x-ray spectrometer; superconductor; x-ray spectra.

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Fast and Easy Identification of Explosives and Suspected Drugs

FOR U.S. troops in combat, accurately identifying the explosives used in a bomb or an improvised explosive device is critical to understanding enemy resources and capabilities. Thanks to an R&D 100 Award–winning technology called microTLC™, a wider range of unknown explosives compounds can be rapidly detected and identified by a simple-to-use, miniaturized, field-portable kit based on thin-layer chromatography (TLC). Livermore chemist John G. Reynolds led the Lawrence Livermore team that codeveloped the breakthrough instrument with Field Forensics, Inc.

The microTLC kit also allows trained nonexperts to quickly separate and identify illicit drugs and cutting agents, and a wide range of other hazardous materials. Users separate unknown target materials with TLC and then identify the unknowns by directly comparing them with extremely small amounts of well-characterized standard compounds that have been pre-applied on 3- by 5-centimeter aluminum plates. The use of small pre-spotted plates coated with absorbent allows the process to be completed within 5 minutes, greatly assisting first responders and law enforcement in the unequivocal identification of suspect materials in record time.

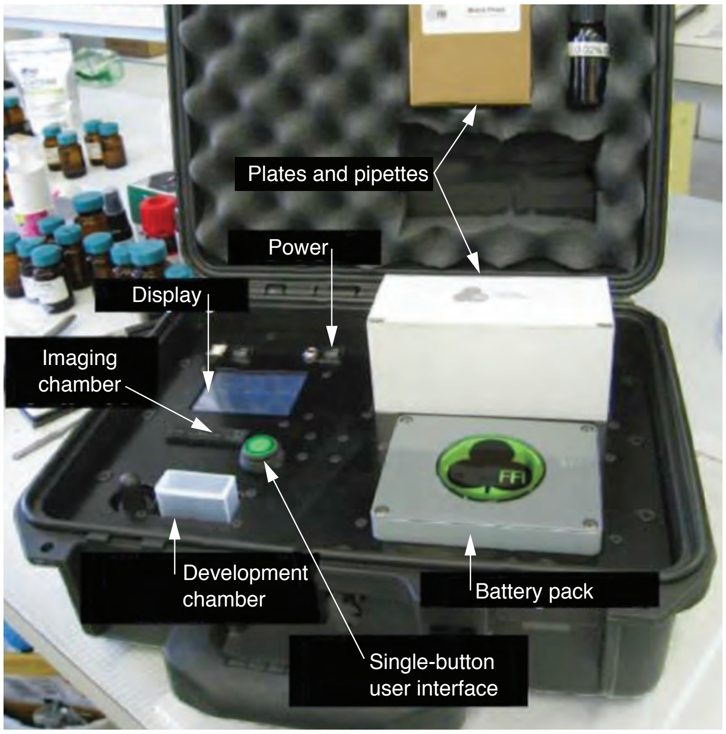
MicroTLC is the latest commercial product to stem from Livermore explosives detection expertise. E.L.I.T.E.™ (Easy Livermore Inspection Test for Explosives) was honored in 2006 with an R&D 100 Award. The E.L.I.T.E. detector weighs less than 30 grams, fits in a shirt pocket, and is sensitive to more than 30 different explosives. (See *S&TR*, October 2006, pp. 16–17.) During the same period, a field kit was developed based on TLC to identify a comprehensive list of explosives and their precursors. "Our field kit did an outstanding job, but it was cumbersome and heavy," says Reynolds. "Our goal was to develop a more portable kit that also would be user friendly and work extremely fast." The result is a compact laboratory for quick, accurate, and inexpensive analysis.

Compact, Lightweight, and Rugged

Reynolds notes that TLC is a long-standing technique used to separate mixtures of substances into their individual components. The technique is known for its simplicity, low cost, accuracy, and sensitivity. In this technique, an unknown compound is identified by comparing the distance it travels in the TLC system with that traveled by a reference compound (standard). The many advantages of TLC are incorporated into the lightweight (less than 1 kilogram) and rugged microTLC kit, making it ideal for the rapid identification of unknowns in the field.

A user first dissolves a sample of unknown material in a solvent enclosed in the kit and with a pipette applies a drop onto one of the

Development team for microTLC™ (thin-layer chromatography): (back row from left) M. Leslie Carman, Ana Racoveanu, and John G. Reynolds; (front row from left) Socorro "Corrie" Painter, Philip Pagoria, and Joe Satcher. (Not shown: Richard Whipple, formerly of Livermore.) (Photo by George A. Kitrinos.)



All of the components required to detect and identify unknown materials are contained in the microTLC™ kit. The small size and ruggedness of the kit permits easy field use as well as rapid identification. In the developing chamber, the spotted plates are mixed with solvent, separating the unknowns. In the imaging chamber, the developed plates are read, and results appear in the display window. The battery pack powers a fan to dry the developed plates and an ultraviolet lamp for reading them.

commercial pre-spotted plates. The plate is then placed in the kit's developing chamber that contains another solvent suspended in a commercial silica-based thickener. As that solvent migrates on the plate, it separates the constituents of the sample. A battery-operated fan dries the plate within 15 seconds of its development. The plate is then examined under ultraviolet (UV) light in the imaging chamber. To identify the suspect materials, the user compares the distance the unknowns traveled with the distance traveled by the reference materials. From start to finish, the spotting process takes less than 5 minutes, and the plate development requires less than 3 minutes. Neither calculations nor operator interpretation are needed, and step-by-step on-screen instructions are provided.

The small plates drastically reduce separation times as well as the amount of solvent required to develop the plates. Including pre-spotted standards reduces identification time, because the reference materials are already located next to the unknown on the separation plate. An innovative aspect of the microTLC kit is the developing solvent suspended in a slurry, which makes handling the plates safer and more user-friendly, while reducing waste.

All the items needed to detect and identify the unknowns are contained in the microTLC kit, including the UV light source and a digital video camera for plate analysis and record management. A battery pack is also included to ensure extended operation in the field. In addition, resupplying the materials, such as the pipettes and TLC plates, is inexpensive compared with other identification systems.

Easy Field Use

With its small size, ease of operation, light weight, and ruggedness, the microTLC kit lends itself to field use much more so than conventional methods such as mass spectrometry and molecular spectroscopy. The principal application for the kit is military monitoring of explosives. For detecting and identifying military explosives, the plates are pre-spotted with explosives standards such as TNT (trinitrotoluene), tetryl, picric acid, RDX (1,3,5-trinitro-1,3,5-triazacyclohexane), and HMX (1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane), thereby eliminating the need to apply these standards in the field. The pre-spotted plates remain viable for more than one year. The kit operates the same for detecting and identifying illicit drugs, but the plates are pre-spotted with illicit drug standards.

The microTLC kit is exceptionally sensitive. Following the detonation of an explosive device, the instrument can detect residue measuring a few nanograms (billionths of a gram). For suspected drug trafficking, swiping a door handle for residue may well provide enough material for comparison to a known standard and unequivocal positive identification. Reynolds says, "With its extremely low power requirements, low cost, and ability to work in conditions not typically conducive for laboratory equipment, the microTLC kit has greatly advanced our ability to quickly detect and accurately identify a wide range of hazardous materials in the field."

—*Arnie Heller*

Key Words: explosives detection, thin-layer chromatography (TLC), microTLC™, R&D 100 Award.

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Novel Process Advances Optical Glass Polishing

POLISHING glass optics to their final shape using conventional full-aperture methods requires multiple process iterations and is labor intensive. However, a new Lawrence Livermore technology, called convergent polishing, markedly reduces the cost, labor, and time required to polish an optic.

The novel system, a winner of an R&D 100 Award, polishes in a single iteration both flat and spherical glass components regardless of the workpiece's initial shape. The process replaces conventional polishing methods that are largely artisan-based. In these methods, skilled laborers, such as master opticians, polish a workpiece through multiple, iterative cycles requiring many interim measurements and process adjustments.

With the new technology, a workpiece can be polished in a single work shift without operator intervention. Initial and intermediate metrology measurements, which add to the length of the process, personnel time, and workpiece handling risk, are not required. While conventional polishing typically requires approximately 24 hours (and occasionally 100 or more hours), the convergent polishing process takes just 4 hours.

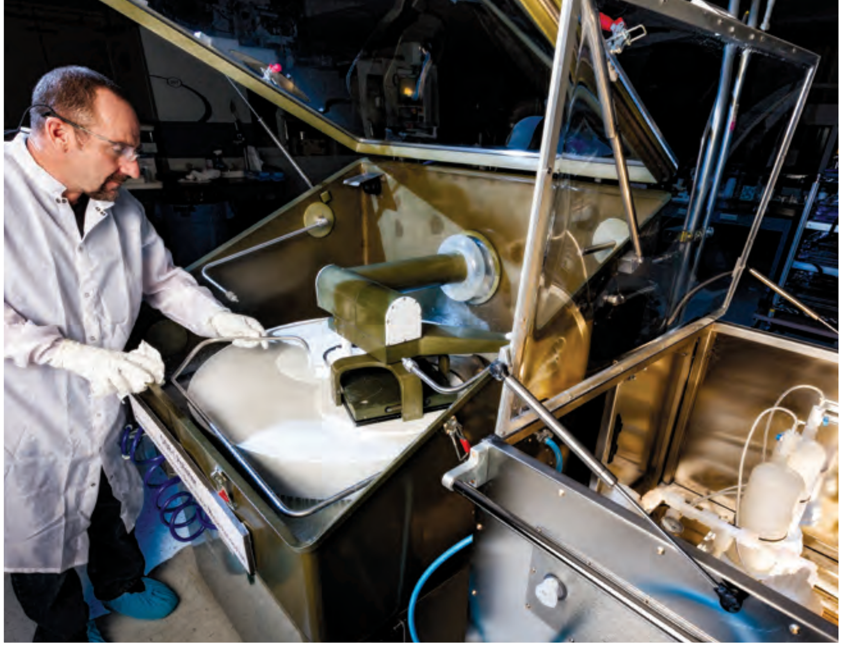
Designed for Lasers, Imaging, Lithography

The technology's principal applications include manufacturing optics used in high-power or high-energy lasers, imaging systems, and lithography as well as manufacturing optical components of various sizes and shapes with different glass compositions. A prototype machine built by Livermore researchers, called the CISR (convergent, initial-surface-independent, single-iteration, rogue-particle-free) polisher, incorporates the breakthrough method.

The prototype CISR polisher has produced pieces made of fused silica, borosilicate, and phosphate glasses, ranging from 70 to 265 millimeters in diameter or length. Livermore researchers plan to build a second pilot machine, which will be capable of finishing 0.5-meter-scale replacement optics for Livermore's 192-beam National Ignition Facility. In addition, glass-polishing companies may purchase the rights to build a convergent polishing machine and tailor its specifications to their needs.

Materials scientist Tayyab Suratwala, who led the award-winning team, explains that in the conventional manufacturing of a precision optic, a roughly cut glass slab is slowly polished to a smooth surface

Development team for convergent polishing: (from left) Tayyab Suratwala, Doug Fisher, Nan Shen, Paul Geraghty, Rebecca Dylla-Spears, Lana Wong, Ed Northcutt, Rusty Steele, John Bigelow, Mike Feit, Rich DesJardin, Dan Mason, and Phil Miller. (Photo by George A. Kitrinos.)



Steele inspects the slurry feed used by the prototype CISR (convergent, initial-surface-independent, single-iteration, rogue-particle-free) polisher. To the right of the polisher is the slurry filtration unit. (Photo by Damien Jemison.)

of a specified thickness, with a surface height variation of just a few hundred nanometers. The major steps in this tedious process include shaping and grinding (which rapidly removes material), full-aperture polishing (which more slowly removes material across the entire workpiece through chemical–mechanical interactions), and at times small-tool polishing (which is performed over small sections of the workpiece).

Suratwala notes that significant advancements have been made over the past two decades in the shaping, grinding, and small-tool polishing steps to meet increasing demand for high-quality optical components. However, the intermediate step of the finishing process—full-aperture polishing—still lacks a high degree of predictability. This step typically requires skilled opticians to carry out iterative cycles with multiple measurements and adjustments. Often master opticians must supervise the laborious polishing process. "The variety of polishing methods, process variables, and complex chemical and mechanical interactions between the workpiece, polishing pad, and slurry have made it challenging to transform optical polishing from an art to a science," says Suratwala.

Method Relies on Natural Shape "Convergence"

In contrast, convergent polishing represents a significant change from how full-aperture polishing has been conducted for centuries. During this polishing process, the workpiece "converges" to the desired shape and size. The technologies enabling convergence are built into the design and fixed process parameters of the polisher. The polisher does not use real-time feedback, diagnostics, or computer control. Also, overpolishing is not a risk factor as is common with conventional polishing. The system provides high surface quality, which is achieved by controlling particle-size distribution of the polishing slurry and by preventing the entry or creation of rogue (that is, large) particles that can cause scratches.

Two major principles make convergent polishing possible. First, the factors contributing to nonuniform material removal on the workpiece have been eliminated. As a result, the workpiece surface converges to the desired shape. Second, any rogue particles that enter the system are automatically removed during the polishing process. Consequently, the workpiece experiences very little or no scratching, leading to an extremely smooth surface.

The convergent polishing method reflects the lessons learned during an eight-year research effort by the Livermore optics group. This effort involved understanding the phenomena leading to material removal nonuniformities and the effects and types of rogue particles. The group then developed techniques to eliminate or mitigate these perturbations from the optical polishing process. The many key advances resulting from the study include a novel shaped septum, a material loaded on the pad whose shape compensates for nonuniform pad wear and improves temperature stability and slurry distribution. Another example is a unique blocking technique, called pitch button blocking, which uses droplets of pitch (similar to tar) sandwiched between the workpiece and its weight to prevent the workpiece from bending during mounting and polishing. The technique also minimizes the risk of scratching.

Finally, polishing is performed in a hermetically sealed chamber to eliminate external particles that can lead to surface cracks and scratches, which in turn can increase laser damage susceptibility. The chamber is maintained at a very high humidity so the slurry does not harden, which can cause scratches.

The Livermore team is confident convergent polishing will make a much needed—and long awaited—improvement to a venerable manufacturing process.

—Arnie Heller

Key Words: CISR (convergent, initial-surface-independent, single-iteration, rogue-particle-free) polisher, convergent polishing, fused silica, glass optics, R&D 100 Award.

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The Power of Combined Laser Light

FROM their use in technologies as simple as laser pointers to as complex as the National Ignition Facility, lasers have a wide range of applications in today's world. Typically, laser-based devices rely on a single-output system, where the laser is produced from a solitary source and then amplified through sophisticated optics. In contrast, spectral beam combining (SBC) is a technique in which several individual beams with nonoverlapping optical spectra are combined to produce one high-power beam.

SBC systems generally use fiber lasers as the beam source because they are robust, efficient, and compact. Fiber lasers can also operate over a range of wavelengths. The lasers are coupled with a dispersive optical element, such as a diffractive grating or prism, which can deflect incident beams according to each beam's wavelength and spatially overlap the beams so that they propagate in the same direction. However, these optical elements typically cannot handle the higher power needed for advanced material processing applications, scientific research, and certain military purposes.

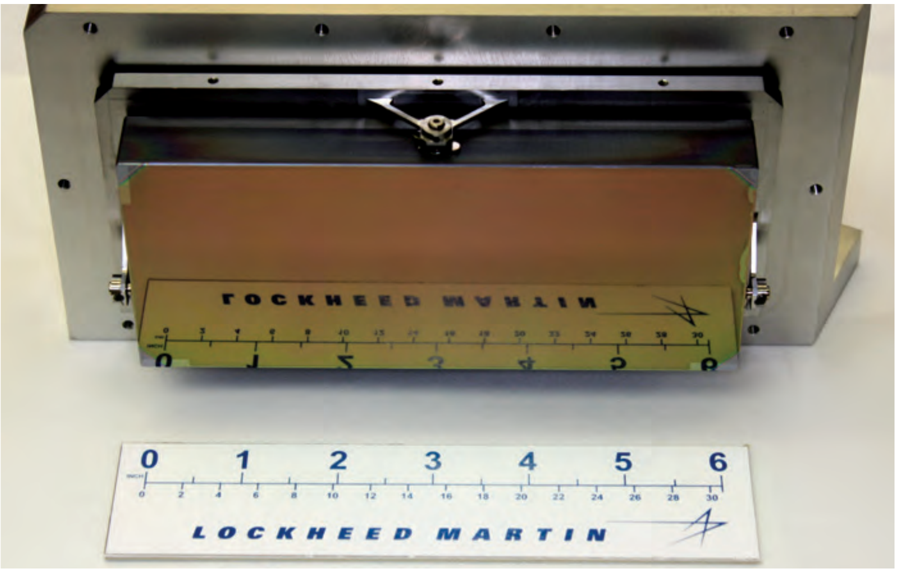
An R&D 100 Award–winning team comprising researchers from Lawrence Livermore, Lockheed Martin, and Advanced Thin Films, Inc., has developed the extreme-power, ultralow-loss, dispersive element (EXUDE) for adapting SBC to high-power applications. EXUDE integrates improved optical coatings, a novel surface-relief grating structure, and innovative fabrication and processing techniques to enable an electrically efficient, near-diffraction-limited multikilowatt SBC laser system.

Scaling Up the Power

The increased demand for high-power laser sources with diffraction-limited beam quality has led to significant scaling in the output power of laser systems. Attempts at scaling single-output lasers to more than 100 kilowatts has revealed issues with removing waste heat, maintaining beam quality, and avoiding optics damage at the higher powers. Electrically driven solid-state lasers have demonstrated more than 100-kilowatt output, but thermo-optical distortions in the bulk laser materials degraded beam quality, limiting the beam's irradiance.

An SBC system that can effectively combine diffraction-limited beams of varying wavelengths into a single beam with broad gain bandwidth provides a straightforward approach to power scaling. Until EXUDE, the output power of SBC systems was limited by the ability of the beam combiner to minimize power loss. EXUDE is a precisely designed and fabricated surface-relief grating structure embedded into the topmost

Development team for the extreme-power, ultralow-loss, dispersive element (EXUDE): (from left) Hoang Nguyen, Curly Hoaglan, James Nissen, Cindy Larson, Tom Carlson, Jerry Britten, and Mike Aasen. (Photo by George A. Kitrinos.)



EXUDE is a surface-relief grating structure embedded into the topmost layer of a highly reflective, multilayer dielectric thin film. The device spectrally combines laser beams from multiple sources into a single, high-power beam to achieve unprecedented output levels. (Photo courtesy of Lockheed Martin.)

layer of a highly reflective, ultralow-loss, multilayer dielectric thin film.

EXUDE combines the beams from many laser sources of the same type, in particular fiber lasers, wherein the sources operate at specific wavelengths. The operating wavelength and incidence angle of each fiber laser is tuned to a precise value so that all of the output beams overlap to produce a single beam. Because fiber lasers can produce nearly diffraction-limited beams at very high electrical to optical efficiency, the output of the SBC system can also be nearly diffraction-limited, with minimal loss resulting from the element itself.

In a recent demonstration conducted by Lockheed Martin, the EXUDE-based SBC system successfully combined fiber lasers into a single 30-kilowatt beam of light. “Even at these high powers, our EXUDE optic maintained excellent efficiency and beam quality, paving the way for advanced defense applications,” says Jerry Britten, the Livermore team lead. “EXUDE also provides the laser industry with a way to meet critical commercial demands for compact, highly efficient, multikilowatt laser systems.”

An Expert Collaboration

EXUDE provides an excellent example of how experts in different scientific and research disciplines can work together to create technologies with superior capabilities. “Livermore was responsible for designing and fabricating the surface-relief grating structure that enables multiple output beams at different angles to come off an optic at the same angle, allowing their powers to add,” says Britten. The diffraction grating is manufactured on top of an optic that comprises a multilayer stack of high- and low-index materials to provide the maximum diffraction efficiency.

Advanced Thin Films, Inc., fabricated the ultralow-loss multilayer dielectric films for the optic. The proprietary optical coating, designed by Livermore, allows for the stacking of more than 100 film layers to achieve ultralow-loss, parts-per-million transmission levels, high diffraction efficiency, and large bandwidth. The company also postprocessed the films to ensure a flatter diffractive wave front. The surface-relief grating structure is precisely impedance matched to the thin-film stack for improved optical performance. Additionally, both the surface-relief grating structure and the optical thin films can be placed on thermally conductive materials.

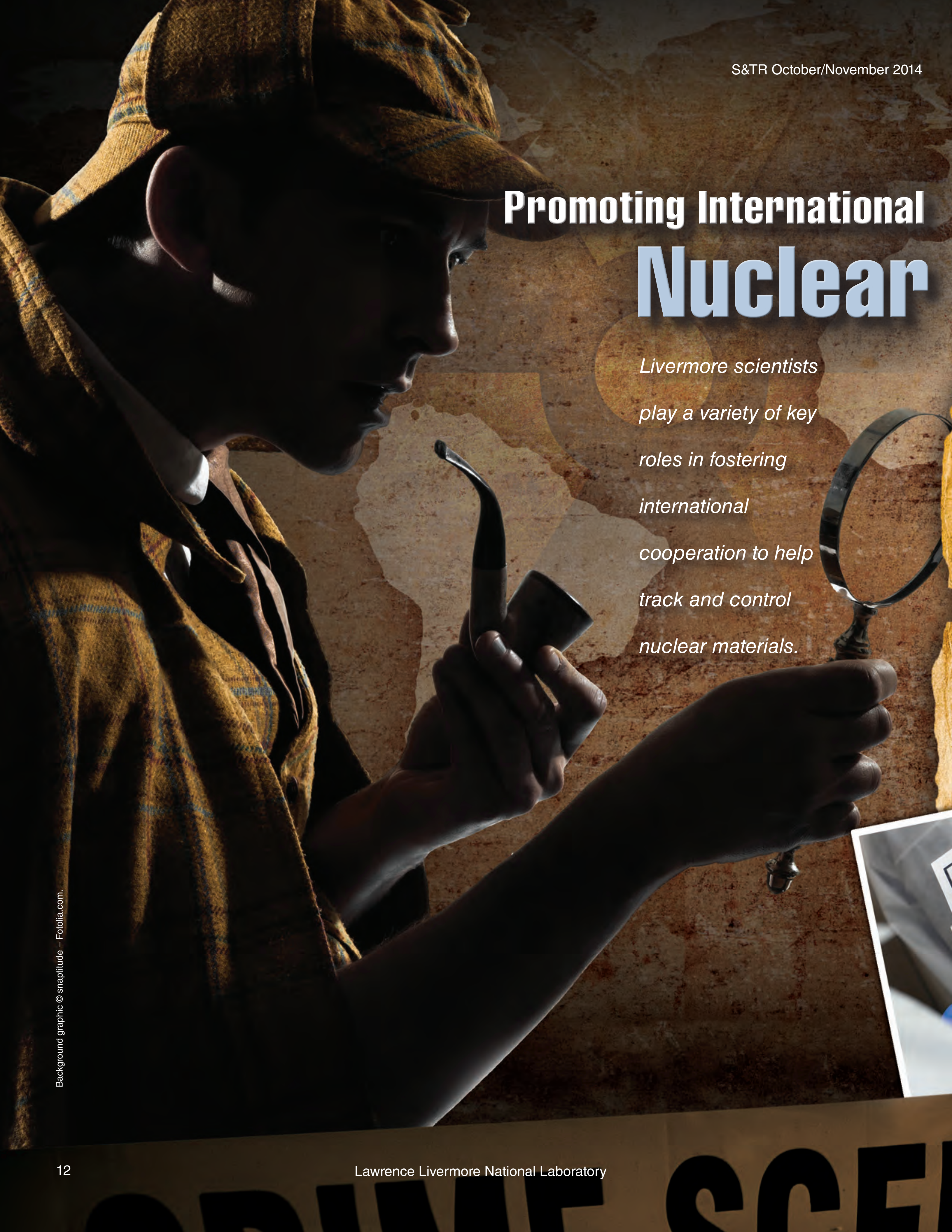
The final gratings were delivered to Lockheed Martin, which integrated the components with the rest of the fiber-laser hardware and conducted the tests. “The 30-kilowatt demonstration validates our approach for an efficient, near-diffraction-limited, high-power laser system,” says Britten. “In the future, we expect to achieve significantly higher power levels to address critical defense needs.”

Through this collaboration, the EXUDE team proved that unprecedented efficiency and beam quality can be achieved in a high-power system by spectrally combining fiber lasers or other types of lasers to the desired output powers. Furthermore, the modular approach of using multiple fiber lasers to produce the higher powers simplifies manufacturing and maintainability. With the advent of EXUDE, the range of laser-based applications has been even further expanded.

—Caryn Meissner

Key Words: diffraction-limited; extreme-power, ultralow-loss, dispersive element (EXUDE); fiber laser; output power; R&D 100 Award, spectral beam combining (SBC).

For further information contact Jerry Britten (925) 423-7653 (britten1@llnl.gov).



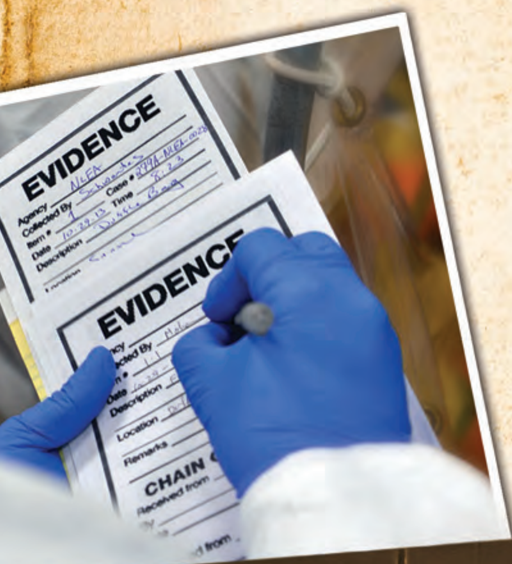
Promoting International Nuclear

Livermore scientists play a variety of key roles in fostering international cooperation to help track and control nuclear materials.

Security through Forensics

THE possibility of the smuggling and trafficking of radiological and nuclear materials has become a very real threat over the past 20 years. A major security concern of the international community is the activity of groups, whether nation-states or terrorists, seeking to obtain such materials for illicit purposes. To address this threat, several national and international endeavors seek to control the spread of nuclear materials as well as the technology and expertise associated with their production and use. In particular, the Office of Nonproliferation and International Security in the Department of Energy's (DOE's) National Nuclear Security Administration and the International Atomic Energy Agency (IAEA) work together to ensure that a system exists to identify the source of any interdicted materials.

Lawrence Livermore is an active participant in these efforts, bringing its many decades of expertise in nuclear weapons design and performance to the newer discipline of nuclear forensics. In nuclear forensics, investigators act as "sleuths," analyzing nuclear or radioactive materials for clues to a material's source to identify where legitimate, legal control was likely lost. An extensive team of Livermore scientists, including Martin Robel, Erick Ramon, and Naomi Marks, is engaged in a number of areas to promote international understanding and collaboration in nuclear forensics and to advance technical capabilities in the field. From building nuclear forensic tools "at home" to teaching good laboratory practices abroad, the Livermore team is engaged in a global undertaking to secure nuclear material and disrupt black market trade.



Nuclear forensics investigators act as sleuths, searching for evidence that will help them determine the history and source of nuclear or radioactive materials found outside regulatory controls. (Photo at left courtesy of Dean Calma/ International Atomic Energy Agency [IAEA].)

Bringing Insight to Databases

Over the last decade, Robel's development of the Uranium Sourcing Database and the innovative database query system DAVE (Discriminant Analysis and Verification Engine) has contributed significantly to the Laboratory's efforts to foster international cooperation in nuclear forensics. Robel first created DAVE to interrogate huge amounts of chemical information on yellowcake, a form of uranium used in the nuclear fuel cycle to make material suitable for enrichment. The information initially arrived on Robel's desk as a spreadsheet containing 34,000 data points for 1,700 samples of yellowcake. Robel used that information as the starting point for creating the Uranium Sourcing Database. The sophisticated database has been expanded to include data for uranium ore and uranium tetrafluoride, which are also materials involved in the early stages of the nuclear fuel cycle. The Uranium Sourcing Database now contains approximately 190,000 data points, representing more than 6,300 samples from 133 distinct sources and 31 different countries.

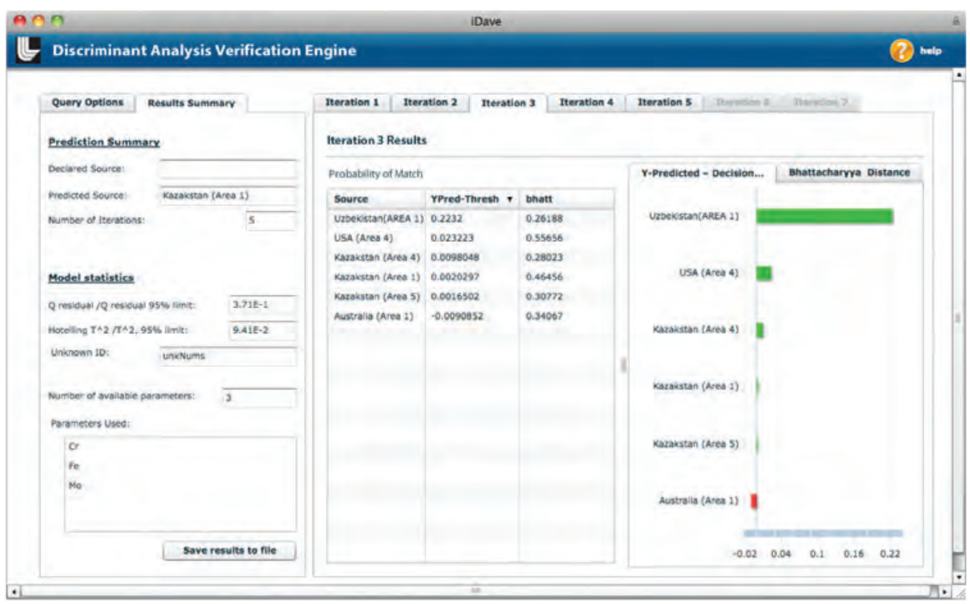
Each sample in the database is defined by 20 to 80 variables, including major and trace element abundances and certain isotope ratios. The number of variables for each sample depends on the organization that conducted the sample analysis and the composition of the sample. Robel explains, “When Livermore analyzes a sample for inclusion in the database, we focus on about 80 variables or criteria, looking for traces of most of the elements in the periodic table as well as making high-accuracy, high-precision, destructive analysis measurements.” In contrast, most sample data submitted from outside organizations have been gathered for quality control and production purposes rather than for nuclear forensics. These analyses usually cover only 20 variables, and the measurements tend to be less precise.

Yellowcake, in particular, is of interest in the nuclear forensics arena for several reasons. First, it contains about 60 to 80 percent uranium, which can be separated into isotopes and enriched to make material suitable for a nuclear explosive device or weapon. Second, it is a commodity, legally traded in large volumes on a global scale. Third, unlike data on plutonium or highly enriched uranium, information about yellowcake is not sensitive, so the data can be used for collaborative research both domestically and internationally. Finally, yellowcake signatures—those distinguishing values or combination of values for a given sample’s variables—are complex, reflecting both the original source ore and the ore’s subsequent processing. “Unlike DNA samples, for instance, yellowcake samples do not have a unique ‘fingerprint,’” says Robel. “Substantial variability exists in material from a particular source.” This variability makes yellowcake a challenging case study for developing nuclear forensic analysis methods.

The Uranium Sourcing Database contains a wealth of information, but it is DAVE, Robel’s innovative query system, that harnesses the database’s potential. DAVE uses advanced statistical methods to quickly identify the most likely sources for an unknown sample. The query system incorporates partial least-squares discriminant analysis (PLS-DA), a powerful statistical method for discriminating between classes of samples (for example, samples from different uranium mines). It also incorporates MATLAB (matrix laboratory), a programming language for manipulating matrices and plotting functions and data. “When one has 70 variables per sample and 1,000 samples, things quickly get complicated trying to compare and discriminate between them,” says Robel.

The PLS-DA algorithm eases the task of discriminating among sample classes by including a dimension reduction step. This step collapses multiple correlated variables into a few “latent variables,” which are not measurable but can be mathematically inferred by the algorithm. Thus, a large number of observable variables can be aggregated in a model to represent an underlying concept, making it easier to understand the data.

At Livermore, Robel teamed up with Justin Shinn of the Technical Information Department and Greg White of the Global Security Principal Directorate to create and implement iDAVE, the



iDAVE, the Web-based discriminant analysis verification engine, created by Livermore researcher Martin Robel and web developer Justin Shinn, discriminates between dozens of yellowcake sources using an iterative process of elimination. iDAVE accepts a remote user’s sample data and returns a predicted source and additional statistics.

Building international communities is key to creating a global, nuclear-secure future. Livermore scientists work with staff from the Nuclear Energy Corporation South Africa (NECSA) to help that country develop its own nuclear forensics laboratory. Here, Livermore researcher Rachel Lindvall (standing) trains NECSA staff on the use of inductively coupled plasma mass spectrometry, an analytic technique for identifying elements. (Photo courtesy of Christina Ramon.)

web application version of DAVE. The iDAVE website, which resides on a special network, allows authorized users to remotely query the Uranium Sourcing Database. iDAVE accepts a sample's data from a remote user, then quantitatively and statistically compares the data to those in the database, and finally, returns a prediction about the source of the unknown with additional statistics.

Livermore's Michael Kristo, associate program leader for Pre-Detonation Nuclear Forensics, notes, "One policy goal of the U.S. and IAEA with respect to nuclear forensics is to encourage the creation of national nuclear forensic libraries. What Robel has created is a fantastic example of what a nuclear forensic database could and should be."

The combination of the Uranium Sourcing Database and DAVE/iDAVE allows Livermore scientists and others to determine the origin of unknown materials sometimes seized on the other side of the globe by police or border security. As part of DOE's international outreach efforts in nuclear forensics, Robel and others involved in this project share the database structure, lessons learned, and the analysis algorithm used in DAVE. Armed with this information, individual countries can build country-specific databases and query systems, creating one of the key capabilities of their own nuclear forensics programs.

Developing Capabilities Abroad

For capabilities such as iDAVE to be most effective, nuclear forensics needs to be encouraged and supported in those areas of the world touched by nuclear trafficking and black market trade. Livermore staff members participate in bilateral engagements with countries such as Ukraine, Russia, France, Kazakhstan, Japan, China, Australia, Korea, and South Africa, helping each country develop the infrastructure and good laboratory practices required for a nuclear forensic facility. Lawrence Livermore is home to some of the world's foremost nuclear forensic experts, including Ian Hutcheon, Pat Grant, and Ken Moody. These three scientists literally wrote the book on nuclear forensics (*Nuclear Forensic Analysis*, the first primary reference source in the field). It is thus fitting for Livermore to be deeply engaged in this international effort to assist those countries interested in developing their own domestic capabilities.

Every country, Ramon notes, is different. "There isn't a one-size-fits-all blueprint for setting up a nuclear forensic capability," he says. "That's where the Laboratory comes in. We provide experts to answer questions, offer guidance and suggestions, and share tools and capabilities." Ramon participates in the South Africa engagement, which is aimed at developing that country's expertise in nuclear materials characterization. Ramon and Hutcheon, who is the Livermore lead for the engagement, provide assistance and advice with practical issues such as the setup and operation of laboratory facilities and equipment.

South Africa is an example of a country that has developed a credible nuclear forensic capability. Hutcheon explains that although South Africa abandoned its nuclear weapons program in the 1990s, the country retained an ongoing program in nuclear safeguards. After participating in the Nuclear Forensics International Technical Working Group meetings sponsored by the G8 countries (a group of eight highly industrialized nations), South Africa indicated its interest in developing a nuclear forensic capability. In 2011, Lawrence Livermore and Los Alamos national laboratories and the Nuclear Energy Corporation South Africa (NECSA) signed a memorandum of understanding that allowed Livermore and Los Alamos to provide ongoing support to South Africa through the state-owned NECSA.

NECSA performs research and development in nuclear energy and radiation sciences and is responsible for processing source material, including uranium enrichment, as well as cooperating with other institutions locally and globally on nuclear and related matters. "Through NECSA, South Africa came into this engagement with well-educated, outstanding scientists and a robust skill set," says Ramon. For several years, Lawrence Livermore and NECSA have worked closely to build new forensic laboratories in Pretoria, South Africa, and train NECSA scientists in analysis methods. This training is critical to building an international network of sleuths who can compare results and track down nuclear material trafficking.

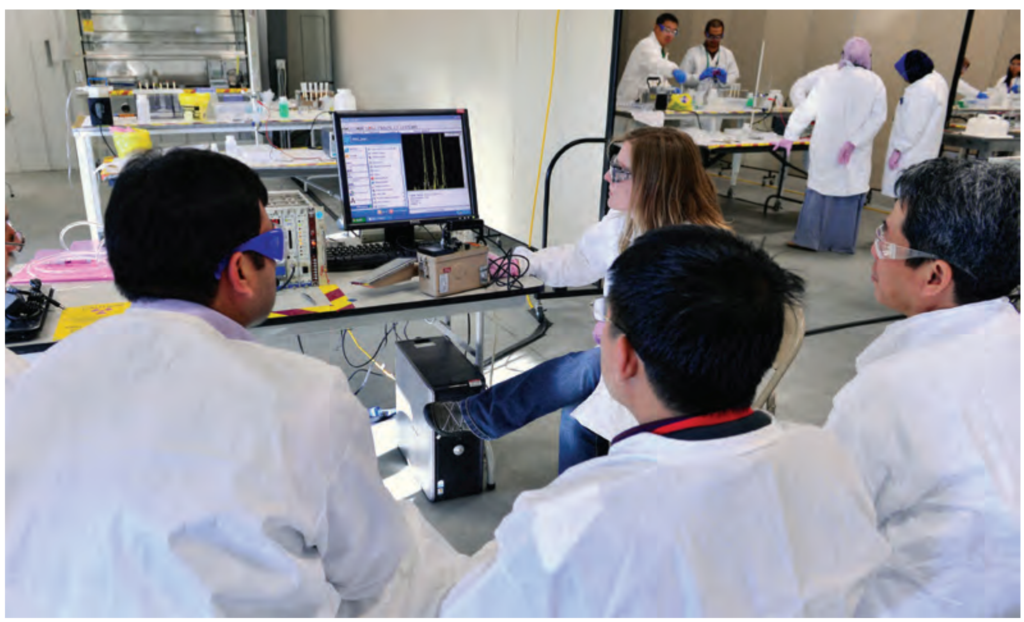
NECSA was able to test its capabilities under real conditions in December 2013, when police seized an unknown radioactive material in Durban, South Africa. "Because we had this memorandum in place, Livermore and NECSA could share aliquots of sample material and compare results of our parallel analysis," explains Hutcheon. In July 2014, Lawrence Livermore and NECSA presented their joint findings in Vienna, Austria, at the IAEA International Conference on Advances in Nuclear Forensics: Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control. Ramon says, "It's a win–win situation for both countries, in that the U.S. would like to have regional partners whose analytical results we trust as much as our own."

The International Classroom

One answer to the puzzle of how to bring international nuclear forensics to the world is bilateral engagements, and another is multilateral meetings. These events serve to bring the larger international community together to share information and continue training in state-of-the-art nuclear forensics. Marks is part of a DOE team of experts who meet annually to conduct the International Workshop on Nuclear Forensics Methodologies, which is hosted by Pacific Northwest National Laboratory at the Volpentest HAMMER Federal Training Center in Richland, Washington.

The joint DOE/IAEA two-week workshop trains representatives of member states in the methods of nuclear materials characterization. The workshop includes classroom and laboratory instruction on technical forensic investigations of nuclear security incidents. Participants are selected by IAEA from a pool of individuals nominated by their home countries. As Marks notes, "We have participants who come from law-enforcement agencies, the military, and utilities as well as from organizations such as the Pakistan Atomic Energy Commission. Some are well versed in the subject of nuclear chemistry or forensics, while others are not. So we start with the basics."

The curriculum focuses on the role of scientists and lab technicians in analyzing



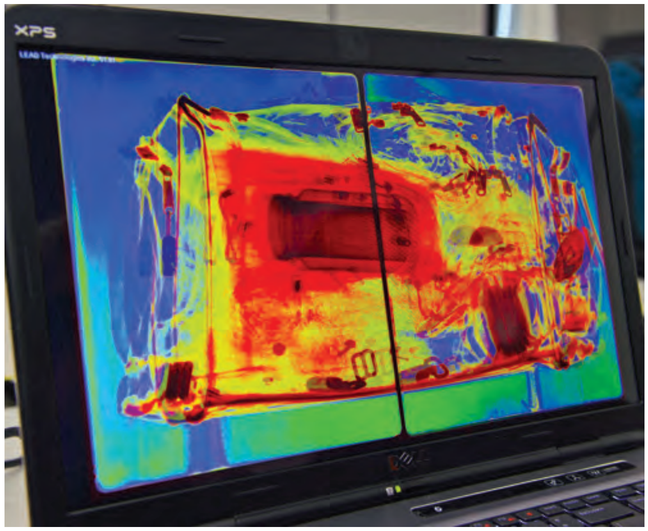
The National Nuclear Security Administration's Office of Nonproliferation and International Security and IAEA cosponsored a second International Workshop on Nuclear Forensics Methodologies at Pacific Northwest National Laboratory in Richland, Washington, in the fall of 2013. The workshop included 26 participants representing 10 countries: Algeria, Bulgaria, Czech Republic, Indonesia, Malaysia, Mexico, Pakistan, Singapore, Thailand, and Vietnam. Participants learned all the steps in an investigation from collecting evidence to analyzing data. (Photo courtesy of Dean Calma/IAEA.)

nuclear and other radiological forensic evidence. Marks, who is instrumental in developing the course syllabus, explains that the curriculum is "scenario-based," highly interactive, and includes hands-on exercises in a simulated forensic investigation of a nuclear material smuggling incident. "The participants role-play different characters throughout the scenario, beginning with a border guard, then a nuclear forensic lab worker, and finally, a national point of contact," says Marks. "In this way, they learn what's involved in every step of the nuclear forensic investigation."

The scenario begins with real vehicles—from small passenger cars to large commercial semitrailers—driving through a transportation portal. Participants use handheld radiation detection devices to determine if the material the driver is carrying matches what is on the manifest. When they find something questionable, the students then plan and conduct an "investigation." They use traditional and nuclear forensic techniques to determine if the conditions for a radiological crime scene exist. The participants are trained in the use of glove bags, radiological controls, and gamma spectrometry. They also learn how to prepare samples for alpha spectrometry. In addition, participants determine if their investigation would benefit from destructive analysis, including mass spectrometry. Throughout the investigation, participants gather data such as whether the material is radioactive, whether it is enriched, and what isotopes are present and in what amounts.

"We also talk about what a lab should look like, what equipment to include, and the infrastructure required," says Marks. "At a minimum, one needs a clean space. After that, one can add alpha- and gamma-spectroscopy capabilities. Mass spectrometry is great, but pricey in many ways. A mass spectrometer can cost from $200,000 to several million dollars. One also needs a facility to house it, a large power source, and air-handling and temperature control systems. Finally, skilled people are needed to run the facility."

As the course progresses, participants are given the opportunity to address the fundamental question in nuclear forensics: "Is this material, which is out of regulatory



At the hands-on fall 2013 workshop, participants learn traditional forensic techniques, such as how to identify hidden objects using gamma spectrometry and x-ray detection (shown here) methods, as well as more specialized nuclear forensic techniques. (Photo courtesy of Dean Calma/IAEA.)

Livermore scientist Naomi Marks describes some of the imaging techniques used in nuclear forensics at the fall 2013 workshop. (Photo courtesy of Dean Calma/IAEA.)

control, ours?" This final module examines the importance and use of national nuclear forensic libraries (also known as databases). Marks begins by introducing participants to the concept of a database. "Many participants come to the workshop with the idea a spreadsheet is a database," she says. "However, in a database, one uses the data but cannot change the information." In its most basic form, a database is similar to modular storage units in that it provides a structure that can be filled with whatever information is desired. Marks reviews the types of databases, from "flat" to those featuring sophisticated and complex means for assembling and querying data collections.

The participants use the data they have collected in the scenario to query an instructional database. Marks has populated this database with data from 5,000 samples, including medical isotopes, sealed sources, and yellowcake. The data are "synthetic," that is, they look authentic but do not represent real samples. Students query the database using simple query strings to determine if the unknown samples match any of the nuclear material holdings of their imaginary country.

Teaching the course has its challenges and its rewards. "The biggest challenge," says Marks, "is the language barrier. Although the workshop is taught in English, most of the participants speak English as a second, third, or fourth language. The language differences can lead to confusion. The biggest reward for me is helping people understand the importance of nuclear forensic databases and seeing them make giant leaps in understanding those databases."

A Global Solution

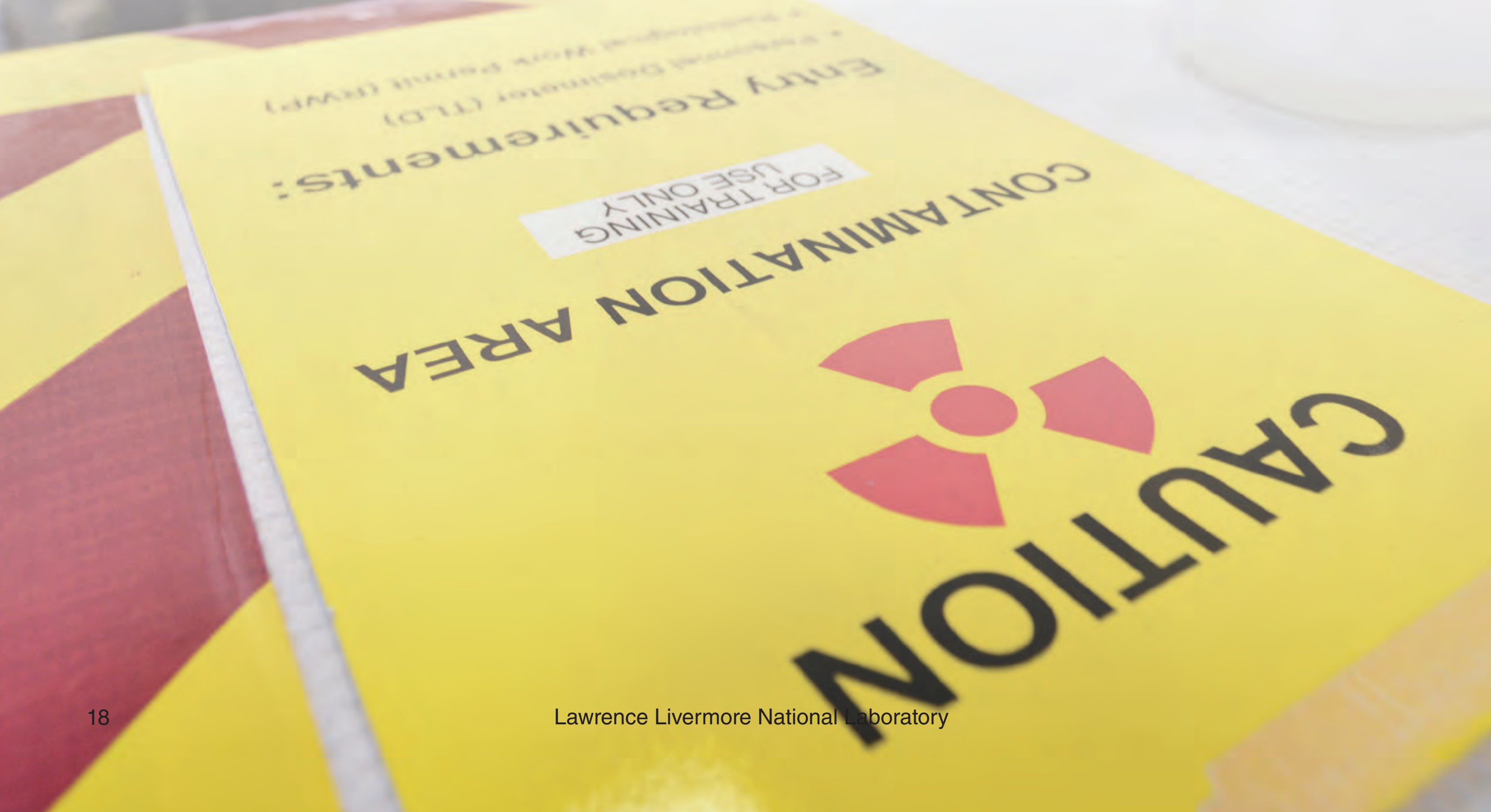
As Kristo and Hutcheon both point out, the U.S. is not alone in its concerns about nuclear terrorism. In his first speech to the United Nations Security Council in 2010, U.S. President Barack Obama called nuclear terrorism "the single most important national security threat that we face." The goal of the U.S. is to encourage "capacity building," that is, improving the ability of other countries to conduct nuclear forensics and, at a minimum, be able to detect materials that are outside regulatory controls.

Building international communities is key to creating a nuclear-secure future. "These are international issues," says Hutcheon, "and global engagement is essential to address the critical 21st-century problem of illicit tracking of nuclear materials." Livermore is working many pieces of the problem, including offering expertise and advice to those interested in developing baseline capabilities in their own countries and building long-term trust and relationships that are key to meeting future national security challenges. Lawrence Livermore's nuclear forensic experts share their knowledge through multilateral and bilateral efforts, workshops, database technology, and direct scientist-to-scientist interactions. Adds Hutcheon, "It's only by working together and helping others to help themselves that we can hope to combat illicit tracking of nuclear materials on a global level."

—*Ann Parker*

Key Words: International Atomic Energy Agency (IAEA), nuclear attribution, Nuclear Energy Corporation South Africa (NECSA), nuclear forensics, nuclear material, partial least-squares discriminate analysis (PLS-DA), uranium ore concentrate, Uranium Sourcing Database, yellowcake.

For further information contact Erick Ramon (925) 422-2588 (ramon1@llnl.gov).



Patents and Awards

In this section, we list recent patents issued to and awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

High Power Density Fuel Cell Comprising an Array of Microchannels

David A. Sopchak, Jeffrey D. Morse, Ravindra S. Upadhye, Jack Kotovsky, Robert T. Graff
U.S. Patent 8,715,882 B2
May 6, 2014
According to one embodiment, this phosphoric acid fuel cell includes an array of microchannels defined by a porous electrolyte support structure extending between the bottom and upper support layers. The array's microchannels include fuel and oxidant microchannels, fuel electrodes running along some of the microchannels, and air electrodes running along other microchannels. A phosphoric acid fuel cell is made according to one embodiment by etching an array of microchannels into a substrate to form walls between the microchannels; processing the walls to make them porous, thereby forming a porous electrolyte support structure; forming anode electrodes along some of the walls and cathode electrodes along other walls; and filling the porous electrolyte support structure with a phosphoric acid electrolyte. Additional embodiments are disclosed.

Classification of Subsurface Objects Using Singular Values Derived from Signal Frames

David H. Chambers, David W. Paglieroni
U.S. Patent 8,717,223 B2
May 6, 2014
This classification system represents a detected object with a feature vector derived from the return signals acquired by an array of N transceivers operating in multistatic mode. The classification system generates the feature vector by transforming the real-valued return signals into complex-valued spectra, using, for example, a fast-Fourier transform. The system then generates a feature vector of singular values for each user-designated spectral subband by applying a singular value decomposition to the $N \times N$ square complex-valued matrix formed from subband samples associated with all possible transmitter–receiver pairs. The resulting feature vector of singular values may be transformed into a feature vector of singular value likelihoods and then subjected to a multicategory linear or neural network classifier for object classification.

Microfluidic Ultrasonic Particle Separators with Engineered Node Locations and Geometries

Klint A. Rose, Karl A. Fisher, Douglas A. Wajda, Raymond P. Mariella, Jr., Christopher Bailey, Dietrich Dehlinger, Maxim Shusteff, Byoungsok Jung, Kevin D. Ness
U.S. Patent 8,727,129 B2
May 20, 2014
An ultrasonic microfluidic system includes a separation channel for conveying a sample fluid containing small and large particles, flowing substantially parallel, adjacent to a recovery fluid, with which it is in contact. An acoustic transducer produces an ultrasound standing wave that generates a pressure field having at least one node of minimum pressure amplitude. An acoustic extension structure is located proximate to the separation channel for positioning the acoustic node off center in the acoustic area and concentrating the large particles in the recovery fluid stream.

Spot Restoration for GPR Image Post-Processing

David W. Paglieroni, N. Reginald Beer
U.S. Patent 8,730,085 B2
May 20, 2014
This imaging and detection system is designed to locate subsurface objects within a medium. In some embodiments, the system operates in a multistatic mode to collect radar return signals generated by an array of transceiver antenna pairs positioned across and traveling down the surface. The system preprocesses the return signal to suppress certain undesirable effects. It then generates synthetic aperture radar images from real aperture radar images generated from the preprocessed return signal. Finally, it postprocesses the synthetic aperture radar images to improve detection of subsurface objects. The imaging and detection system identifies peaks in the energy levels of the postprocessed image frame, which indicate the presence of a subsurface object.

Compounds for Neutron Radiation Detectors and Systems Thereof

Stephen A. Payne, Wolfgang Stoeffl, Natalia P. Zaitseva, Nerine J. Cherepy, M. Leslie Carman
U.S. Patent 8,735,843 B2
May 27, 2014
According to one embodiment, this material exhibits an optical response signature for neutrons that is different than the optical response signature for gamma rays. The material's performance is comparable or superior to stilbene in terms of distinguishing neutrons from gamma rays. Although the material is not stilbene, it is composed of a molecule from a group consisting of two or more benzene rings, one or more benzene rings with a carboxylic acid group, one or more benzene rings with at least one double bond adjacent to the said benzene ring, and one or more benzene rings for which at least one atom in the benzene ring is not carbon.

Echelle Grating Multi-Order Imaging Spectrometer Utilizing a Catadioptric Lens

Michael P. Chrisp, Joel M. Bowers
U.S. Patent 8,736,836 B2
May 27, 2014
This cryogenically cooled imaging spectrometer features a spectrometer housing with two opposing sides. An entrance slit on the first side of the housing directs light to a cross-disperser grating. An echelle immersions grating and a catadioptric lens are positioned in the housing to receive the light. Additionally, a cryogenically cooled detector is located on the second side of the spectrometer housing. Light from the entrance slit is directed to the cross-disperser grating and subsequently to the echelle immersions grating. The light from the echelle immersions grating moves to the cryogenically cooled detector on the second side of the spectrometer housing.

Rigid Spine Reinforced Polymer Microelectrode Array Probe and Method of Fabrication

Phillipe Tabada, Satinderpall S. Pannu
U.S. Patent 8,738,110 B2
May 27, 2014
A rigid spine-reinforced microelectrode array probe includes a flexible elongated probe body with conductive lines enclosed within a polymeric material. These lines connect microelectrodes near an insertion end of the probe to respective leads at a connector end of the probe. The probe also has a rigid spine—made from titanium, for example—to structurally reinforce the probe body and enable the typically flexible body to penetrate and be inserted into tissue, such as neural tissue. By attaching or otherwise fabricating the rigid spine to connect only to an insertion section of the probe body, an integrally connected cable section of the probe body may remain flexible.

Awards

Lawrence Livermore scientists **Charles Westbrook** and **William Pitz** have been named to **Thomson Reuters** list of **The World's Most Influential Scientific Minds: 2014**. The list highlights standout researchers from the past decade, from a compilation of 3,000 of the most influential authors in 21 fields of science or social science. The researchers earned this distinction by writing the greatest number of reports officially designated by essential science indicators as highly cited papers.

Westbrook and Pitz were selected for their numerous research papers on combustion modeling. "One factor for our high publication rate is that we build chemistry models that can be used to interpret experiments and help design internal combustion engines for a wide variety of fuels, including gasoline, diesel ethanol, and biodiesel," says Westbrook. "The key is that, in addition to the papers describing those models, we upload the actual model software, called a chemical kinetic reaction mechanism, to a Lawrence Livermore open-source website. The website has attracted an enormous number of other researchers who want to use our reaction mechanisms in their own work." Pitz notes that what interests them most is enabling the simulation of advanced combustion engines being considered for future vehicles. These engines offer prospects of gains in efficiency and reductions in emissions.

"This recognition is a great honor for Charlie Westbrook and William Pitz and extremely well deserved," says Laboratory Director Bill Goldstein. "It also is indicative of the bright minds working together at Lawrence Livermore to solve some of the nation's most challenging problems."

John Edwards of the National Ignition Facility and Photon Science (NIF&PS) Principal Directorate has received the 2014 **Leadership Award** from **Fusion Power Associates**. The award recognizes Edwards for many scientific contributions and the managerial leadership he is providing to national and international research efforts on inertial confinement fusion and high-energy-density plasma physics. Edwards is cited especially for "leadership of the scientific program on the National Ignition Facility for both high-energy-density physics and for the eventual achievement of ignition leading toward a commercial fusion power source."

"An equally dedicated and talented body of people have built these facilities, kept them running at peak performance, and provided the required targets and diagnostic capabilities," says Edwards. "In addition, much of the progress on NIF this year would not have been possible without the strong encouragement and support of our colleagues at the National Nuclear Security Administration. It is truly an exciting time and a privilege to be part of these efforts."

Research scientist **Zhi Liao** of the NIF&PS Principal Directorate was named a **senior member** of the **Optical Society of America**, an international society for optics and photonics scientists, engineers, educators, and business leaders. Senior membership status recognizes members with more than 10 years of significant experience and professional accomplishments or service in their fields.

Liao received the elevated status in recognition of his contributions to optics research and service to the optics community. His research expertise is in nonlinear optics, adaptive optics, and laser-induced optic damage. Liao has contributed to many of Livermore's successful laser projects, including the Fiber Laser Guide Star, Alkali Laser, Advanced Radiographic Capability, Mercury Laser, and NIF. Since 2005, Liao has been director of the NIF&PS Summer Scholar Program, which includes talks and tours that introduce summer interns to some of the most advanced and exciting research in lasers and photon science.

Abstract

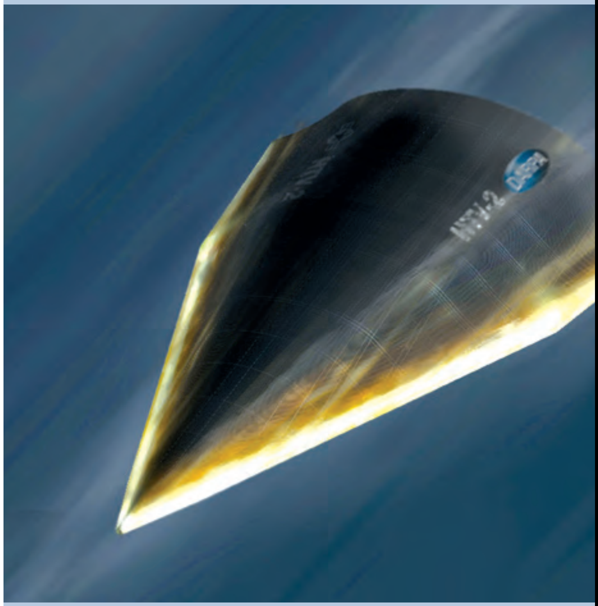
Promoting International Security through Nuclear Forensics

A major security concern of the international community is the activity of groups, whether nation-states or terrorists, seeking to obtain radiological or nuclear material for illicit purposes. To that end, the U.S. and the International Atomic Energy Agency work together to ensure that these materials are protected and a system is in place to identify the source of materials interdicted on the international black market. Livermore scientists, drawing on their decades-long preeminence in nuclear forensics, are involved in a multifaceted effort to develop these capabilities and broadly disseminate them to our international partners.

Contact: Erick Ramon (925) 422-2588 (ramon1@llnl.gov).

U.S. Government Printing Office: 2014/770-075-10006

A Weapon Test at Supersonic Speeds



In collaboration with the U.S. Air Force, Livermore engineers designed and conducted a rocket sled test of a supersonic aerospace vehicle system.

Also in December

• Lawrence Livermore takes bold steps to reduce its environmental footprint and the costs for water and electricity.

• With crystal orientation mapping, scientists can better understand, predict, and control the behavior of polycrystalline materials for additive manufacturing and other applications.

• Livermore scientists are using hard x-ray data from NASA's NuSTAR, the Nuclear Spectroscopic Telescope Array, to explain the diverse properties of neutron stars.

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